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New methodologies to observe wind gusts: research aircraft and Doppler lidar measurements

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To measure wind gusts, a high temporal resolution of the measurement system is needed. Traditionally, wind gust observations have been available only from locations and heights where standard in situ measurement techniques (cup, propeller and sonic anemometers) can be deployed, i.e. from weather stations and meteorological masts. In this study, we have developed new methodologies to derive wind gusts from measurements taken on board a research aircraft (Suomi et al., 2016) and from those by a Doppler lidar (Suomi et al., 2017). Research aircraft can provide gust measurements from remote locations such as the marine Arctic, where traditional measurements are available only from a few coastal stations. Doppler lidar data, on the other hand, can potentially provide valuable information on gust profiles through the full extent of the atmospheric boundary layer, and thereby increase our understanding of the physical processes responsible for gusts.

Aircraft can measure over long distances within a fairly short time interval. The traditional definition for the wind gust, a 3 s maximum of the moving average during a 10 min sampling period, cannot be used. Instead, the gust must be defined with respect to an average over a distance. We developed a new method to compare temporal and spatial scales of turbulence and, based on the results, we chose an optimal length scales for the gust calculation. The resulting gust factors over the marine Arctic yielded results similar to those based on meteorological mast measurements over the Baltic Sea, but there were also some significant differences found.

Doppler lidars can provide profiles of the mean wind speed with a good, known accuracy, but measuring the high-frequency variability in the wind field is more challenging. This is due to their limited temporal resolution and the volume averaging necessary for deriving the 3D wind vector, where information along at least three different lines of sight are combined. For these practical reasons, the measured wind speed maxima are overestimated compared to meteorological mast measurements. To reduce the positive bias, we developed a new scaling technique based on the theoretical behavior of wind gusts as a function of the gust duration. The novel method not only reduces the observed bias but also provides wind gust estimates over a range of gust durations, including those beyond the limit of the Doppler lidar temporal resolution.

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